Ecological and agronomic evaluation of crop rotations in organic farming systems using the model „ROTOR“

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Experimental basis:
Interdisciplinary project ’Nature Conservation Farm Brodowin’

Demeter farm ‘Ecovillage Brodowin’ near Berlin
dairy farm (280 cows); 1240 ha; 90 % arable land; sandy to loamy soils;
540 mm mean annual precipitation

Crop rotation planning is essential for organic farms in order to manage:

- The nitrogen budget and fluxes in fields and within the farm,
- the weed control especially of perennial weeds,
- the control of soil-borne pests and diseases,
- sufficient forage-production,
- environmental & nature conservation issues (non-commodity outputs).

We developed a rule based crop rotation generation & evaluation model (ROTOR):

1. Stand-alone version as a strategic planning tool for individual farms
2. Part of a linear programming multigoal optimisation model (MODAM) for evaluation of economic and ecological effects of organic farming at farm & regional level

Ecological and agronomic evaluation parameters within ROTOR

Evaluation basis: set of predefined annual crop production activities (CPA)

- specific to crop, preceding crop type & soil quality level
- with & without (i) by-product harvest, (ii) manure application (iii) undersown crops, (iv) modified cropping methods for improving the habitat quality of farmland birds

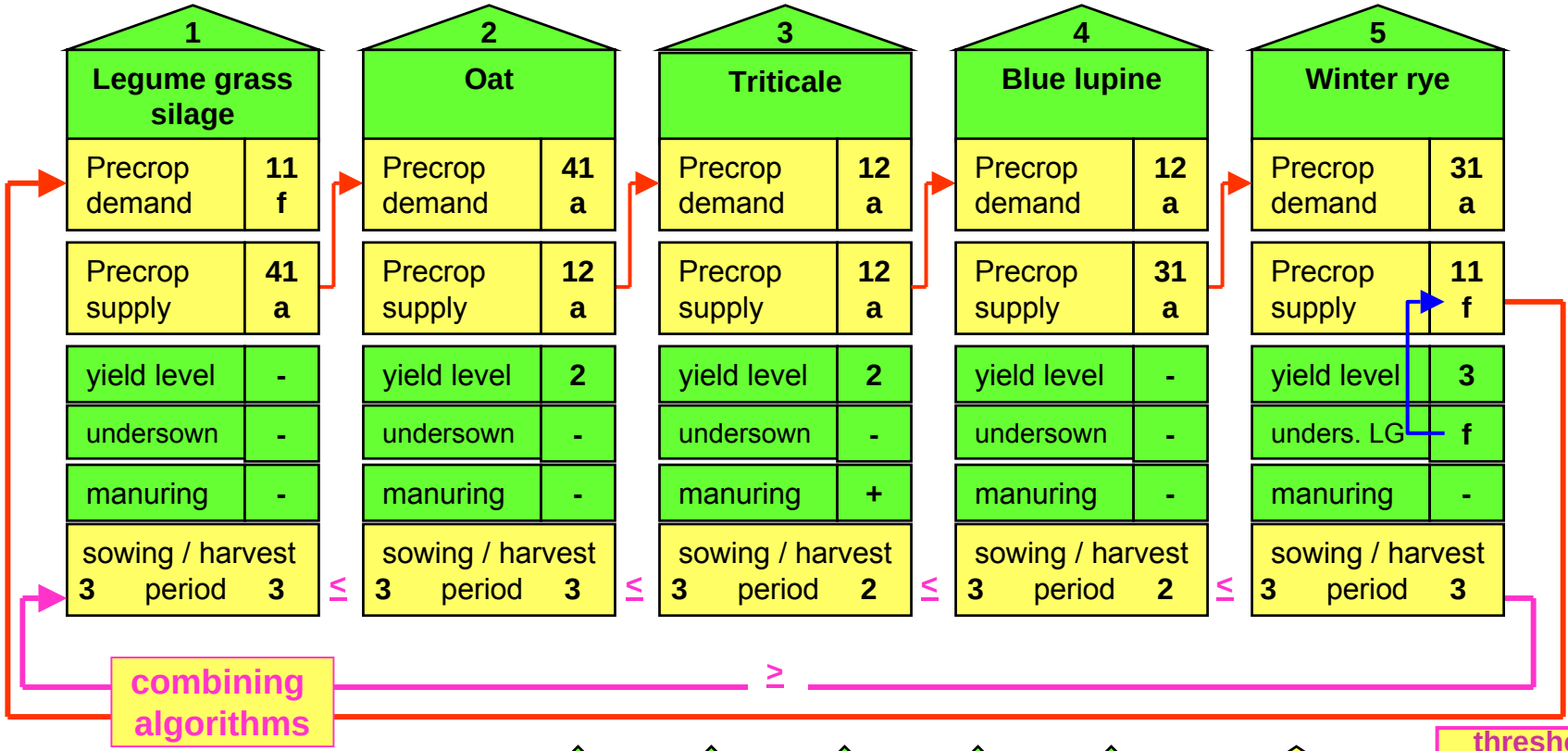
Agronomic evaluation parameters at field level:

- **Yield** (specific to site, crop, preceding crop type & manure application)
- **N-balance** (N-removal, N_2-fixation, NO_3-leaching, manure, ...)
- **Weed infestation risks of perennial, annual winter & spring weeds** (specific to crops & mechanical weed control)
- **Phytosanitary restrictions** (max. frequencies & sequences of crops)

Ecological evaluation parameters:

- **Species diversity of farmland birds** (Skylark, Corn Bunting, Yellow Wagtail, Whinchat, Quail)
- **Territory density (& breeding success) of Skylark**

Example of the generation and evaluation procedure of a crop rotation with ROTOR, using preceding crop specific CPAs, coded with their ‚precrop demand' and ‚precrop supply'



		1	2	3	4	5		CR	threshold values
agronomic exclusion criteria	N-balance [kg ha^{-1}]	60	-37	29	0	-64	∅	-2,4	< - 5% N-Input
	Weedage risk (per.)	0	-1	0	1	0	∅	0	≤ 0
ecological evaluation criteria	N-leaching [kg ha^{-1}]	0	10	22	21	18	∅	14	
	Ter. Skylark [10ha^{-1}]	5,9	4	2,5	3,2	2,3	∅	3,6	

Evaluation results of standard CPAs and modified CPAs for improving the habitat quality

Focus: Territory density of Skylark (territories per 10 ha)

Crop	Standard CPA *)	CPA modified for improving the habitat quality of farmland birds			
		Only blind harrowing	No harrowing	Non-inverting tillage	Threefold drill interspace, no harrowing
Winter rye	2,3	-	2,5	2,8	3,4
Triticale	2,5	-	2,8	3,1	3,7
Winter wheat	2,7	3,0	3,4	-	-
Oat	4,0	4,0	4,5	5,0	5,4
Spring wheat	2,4	2,7	3,1	3,1	-
Spring barley	1,9	2,2	2,4	2,4	-
Pea	2,6	2,8	3,2	3,2	-
Blue lupine	3,2	3,6	4,1	4,1	-
Silage maize	3,2	-	-	-	

	Standard cutting height 7 cm	Modified cutting systems		
		First cut: 14 cm cutting height	Second cut: 2 weeks delayed	Unmown strips: 10 % of the field
Legume grass	5,8	5,8	5,8	5,8

A strong positive effect on the breeding success has been observed, but the data analysis not completed!

*) **Values of standard CPAs (with weeding or standard cutting height) are median values of the observations from 2001 to 2004**

Evaluation results of standard CPAs and modified CPAs for improving the habitat quality

Focus: Species diversity of farmland birds

Crop	Standard CPA	CPA modified for improving the habitat quality of farmland birds			
		Only blind harrowing	No harrowing	Non-inverting tillage	Threefold drill interspace, no harrowing
Winter rye	1,5	-	1,5	1,5	2,5
Triticale	2,0	-	2,0	2,0	3,0
Winter wheat	2,5	2,5	3,0	-	-
Oat	2,5	2,5	3,0	3,0	4,0
Spring wheat	2,0	2,5	3,0	3,0	-
Spring barley	2,0	2,5	3,0	3,0	
Pea	1,5	2,0	3,0	3,0	
Blue lupine	1,5	2,0	3,0	3,0	
Silage maize	2,0	-	-	-	
	Standard cutting height 7 cm	Modified cutting systems			
		First cut: 14 cm cutting height	Second cut: 2 weeks delayed	Unmown strips: 10 % of the field	
Legume grass	2,0	2,5	2	4	

Negative agronomic effects:

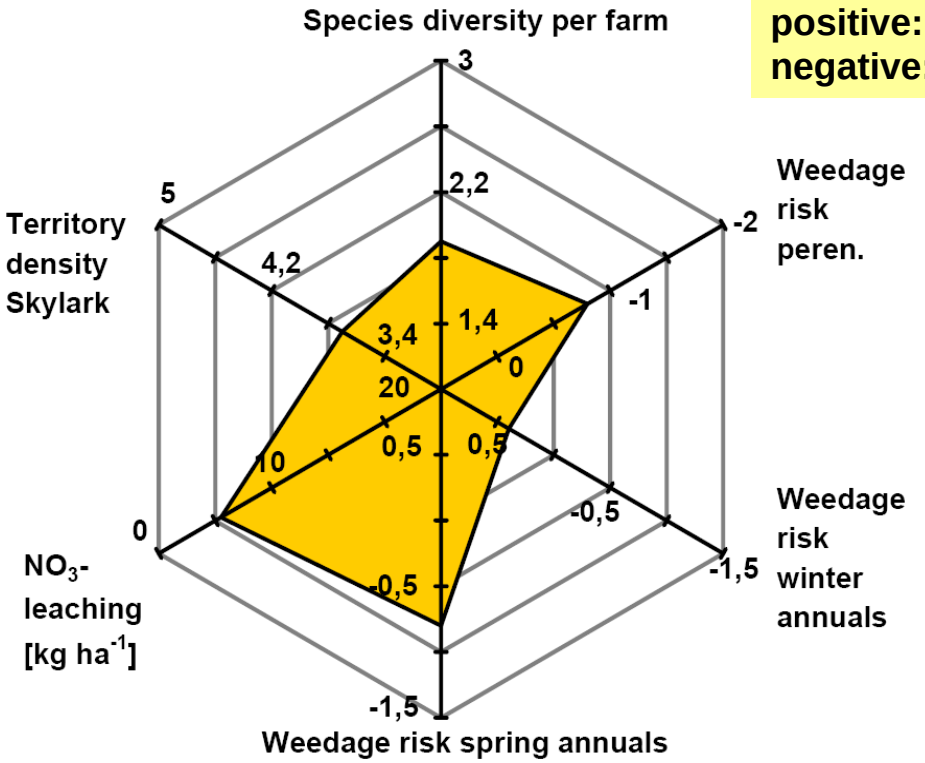
- **weed infest. risk ↑**
- **NO_3-leaching ↑**
- **yield ↓**

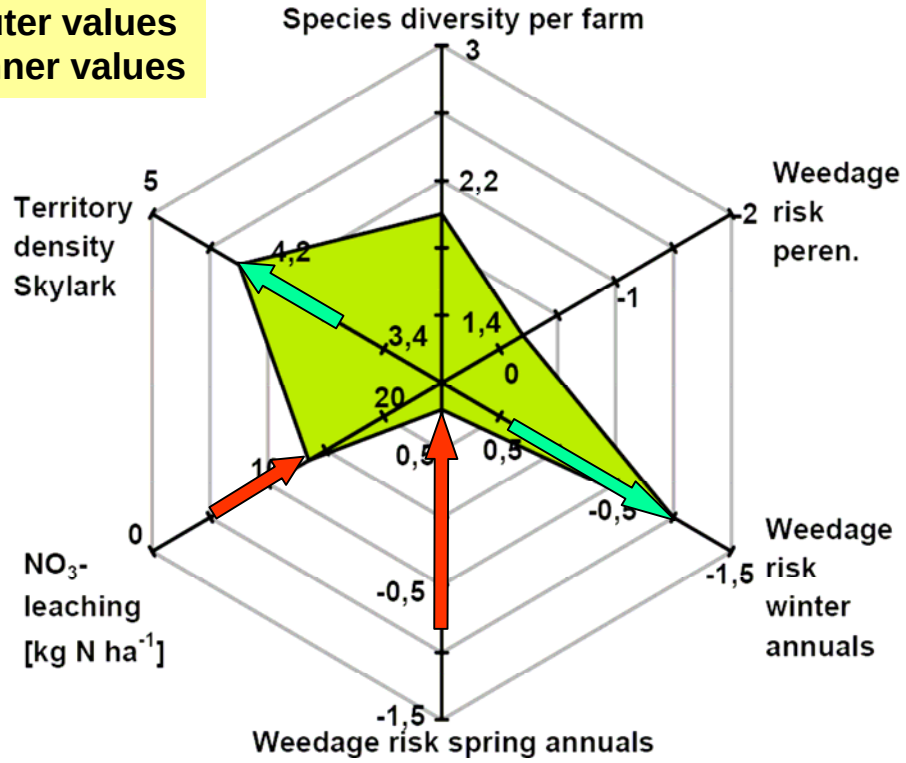
Ecological and agronomic evaluation profiles of two crop rotations without modified CPAs for improving the habitat quality

Rotation 1:	Legume grass (forage)
	Legume grass (forage)
	Spring wheat
	Winter barley
	Winter rye

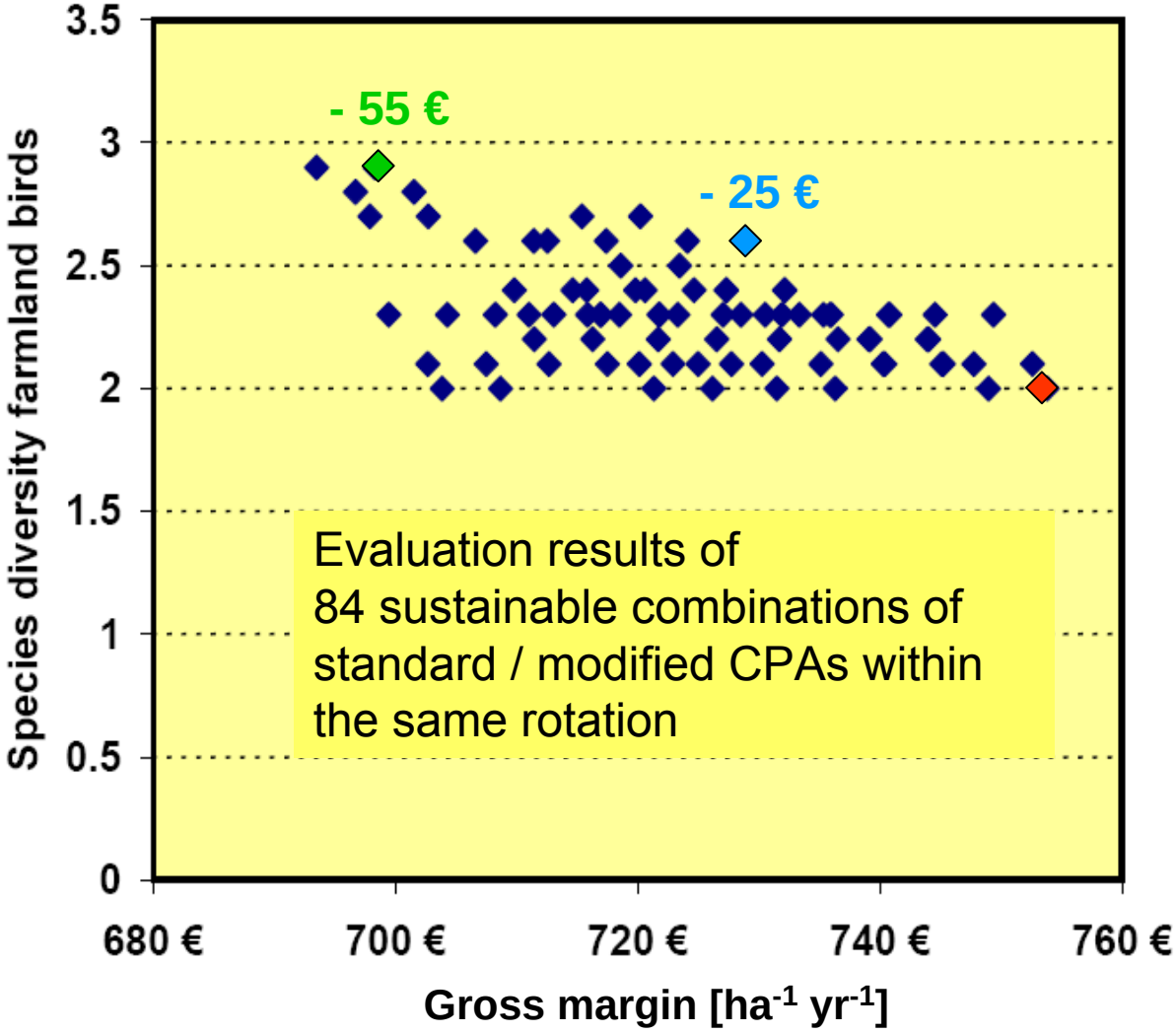
Rotation 2:	Legume grass (forage)
	Legume grass (forage)
	Silage maize
	Blue lupine
	Oat

positive: outer values
negative: inner values



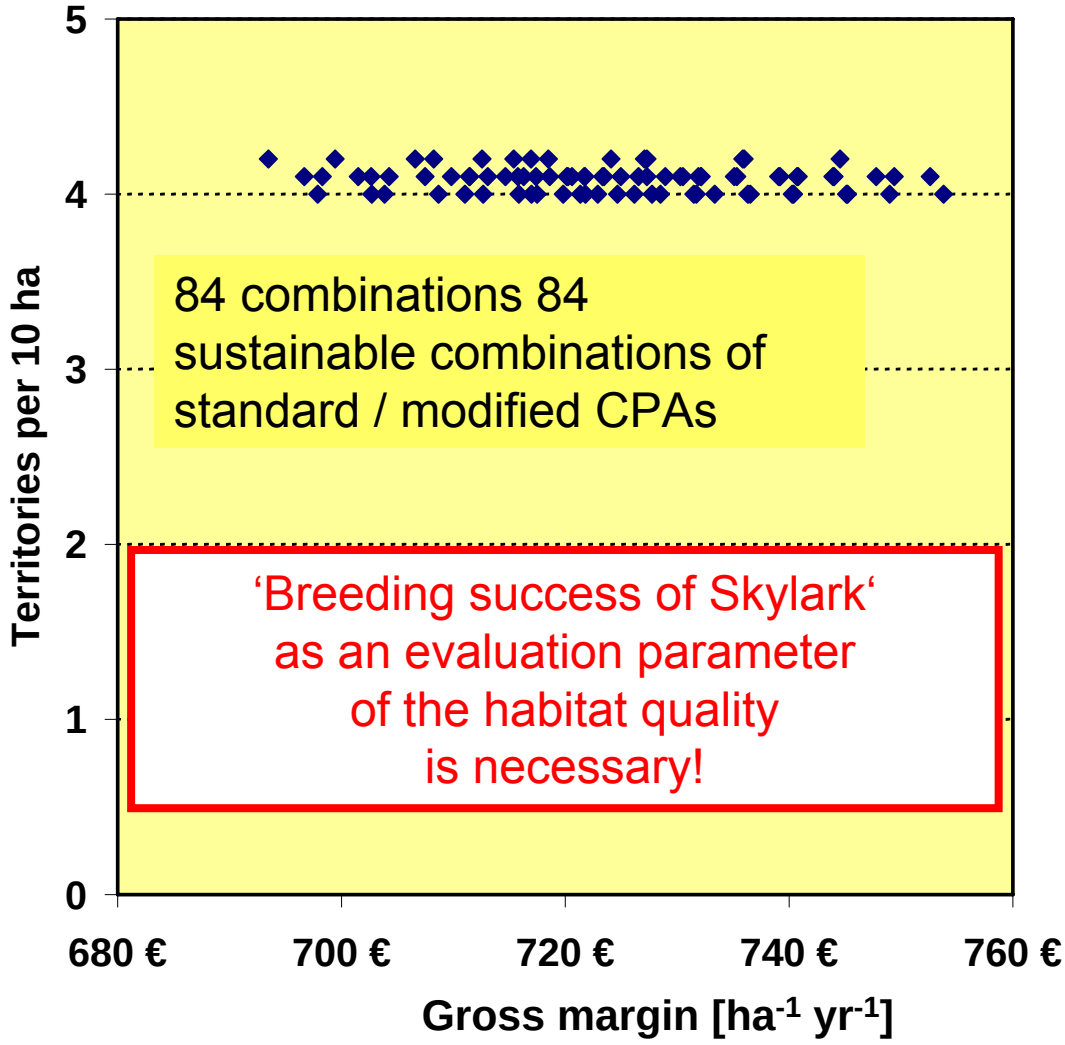


Species diversity of farmland birds versus gross margin of a given 6-course rotation with standard & modified CPAs



1. Legume grass
   Unmown strips
2. Legume grass
   Unmown strips
3. Winter wheat
4. Winter rye
5. Blue Lupine
   No harrowing
6. Oat with leg. grass undersown

Territory density of Skylark versus gross margin of a given 6-course rotation with standard & modified CPAs



1. Legume grass
2. Legume grass
3. Winter wheat
4. Winter rye
5. Blue Lupine
6. Oat with leg. grass undersown

Conclusions & Outlook

- **ROTOR is able to generate 3-8 course site specific crop rotations, taking into account the complex requirements of organic farming systems (e.g. N-supply, cultural weed control, phytosanitary issues).**
- **Crop rotations can be evaluated and selected regarding their abiotic and biotic environmental effects.**
- **ROTOR can be used to select agronomically sound combinations of highly effective nature conservation measures with low economic losses.**
- **As a third important biotic evaluation parameter the breeding success of e.g. Skylark will be implemented.**
- **To improve the practicability of the evaluation parameters of nature conservation measures should be adapted to a wider range of sites and farm types.**

Thank you very much for your attention!

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Weed index: Estimating the risk of infestation with perennial weeds

Assumptions:

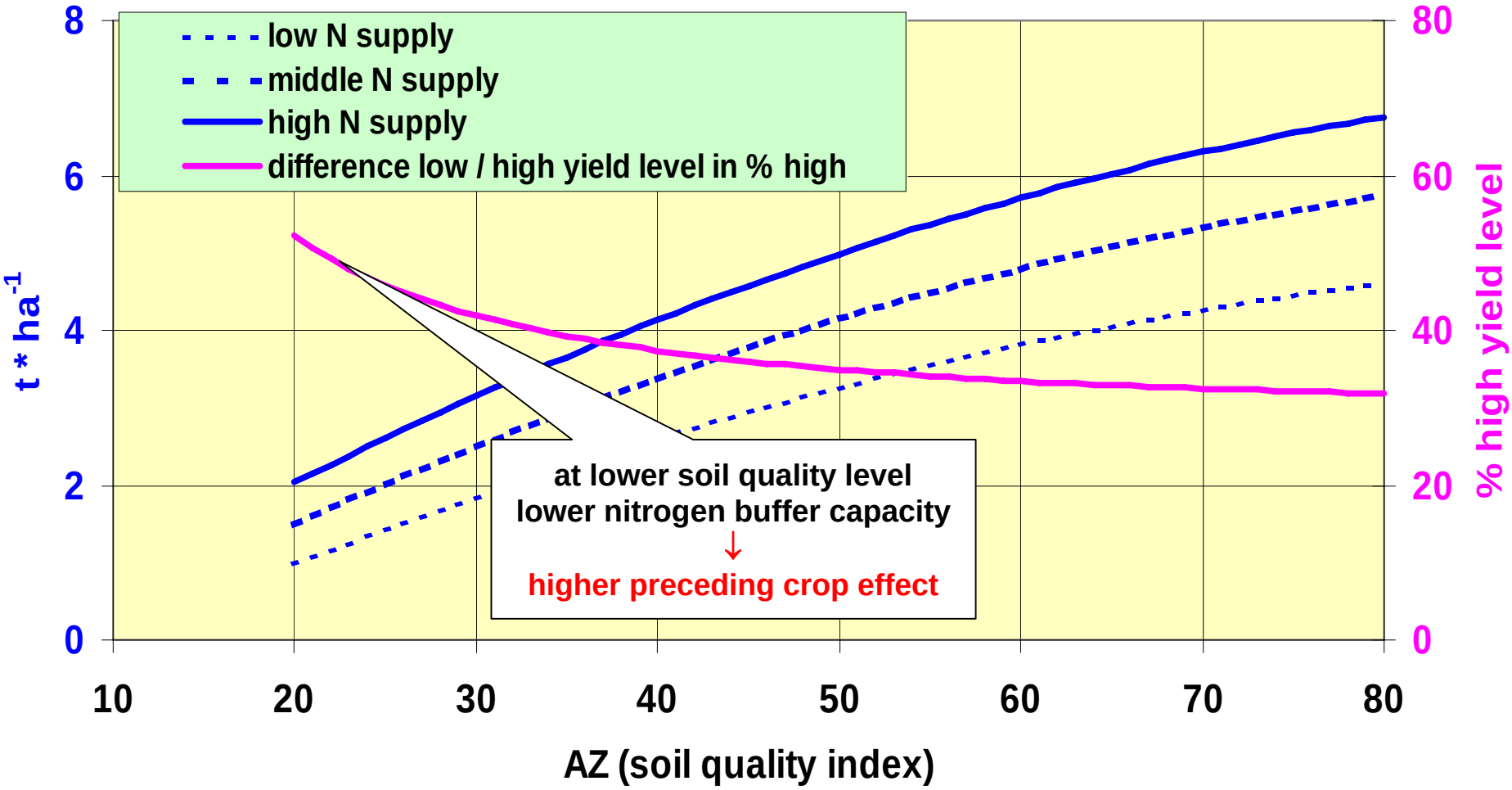
1. the less shading by the crop canopy the higher the weed infestation risk
2. the longer the period between two plough-based tillage operations the higher the weed infestation risk
3. the weed index has to be ≤ 0 for a whole rotational cycle

→ **Assessment of weedage risk for different crops and cropping techniques**

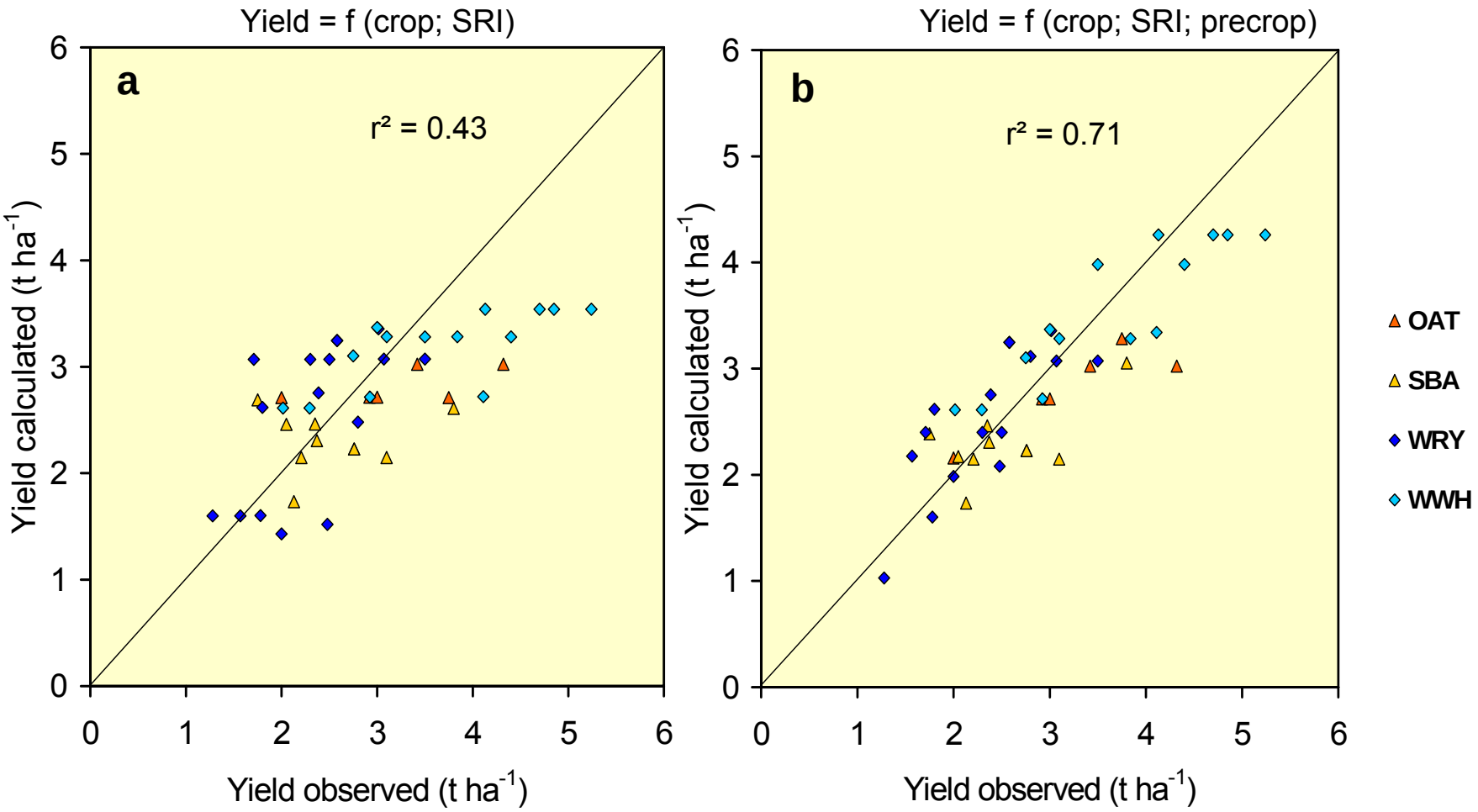
	weed index (knowledge based) decreasing <----------> increasing risk of infestation by perennial weeds										
	-0.6	-0.4	-0.3	-0.2	-0.1	0	0.1	0.2	0.3	0.4	0.5
winter cereals				WRY	WBA		WWH				
spring cereals					OAT	SBA					
oil seeds				WRA			LIS				
row crops			POT								
legume grass						LG					
grain legumes						FAB	PEA	LUP			
no-plough tillage									X		
cultural weed control *)	X										
catch or cover crop					X						
underseeding in winter cereals								X			
underseeding in grain legumes							X				
underseeding in spring cereals								X			

*) = 1 x cultivator, 2 x disk harrow, 1 x share plough with jointers

Yield functions of winterrye depending on soil quality (AZ) and on the level of nitrogen supply caused by different preceding crops

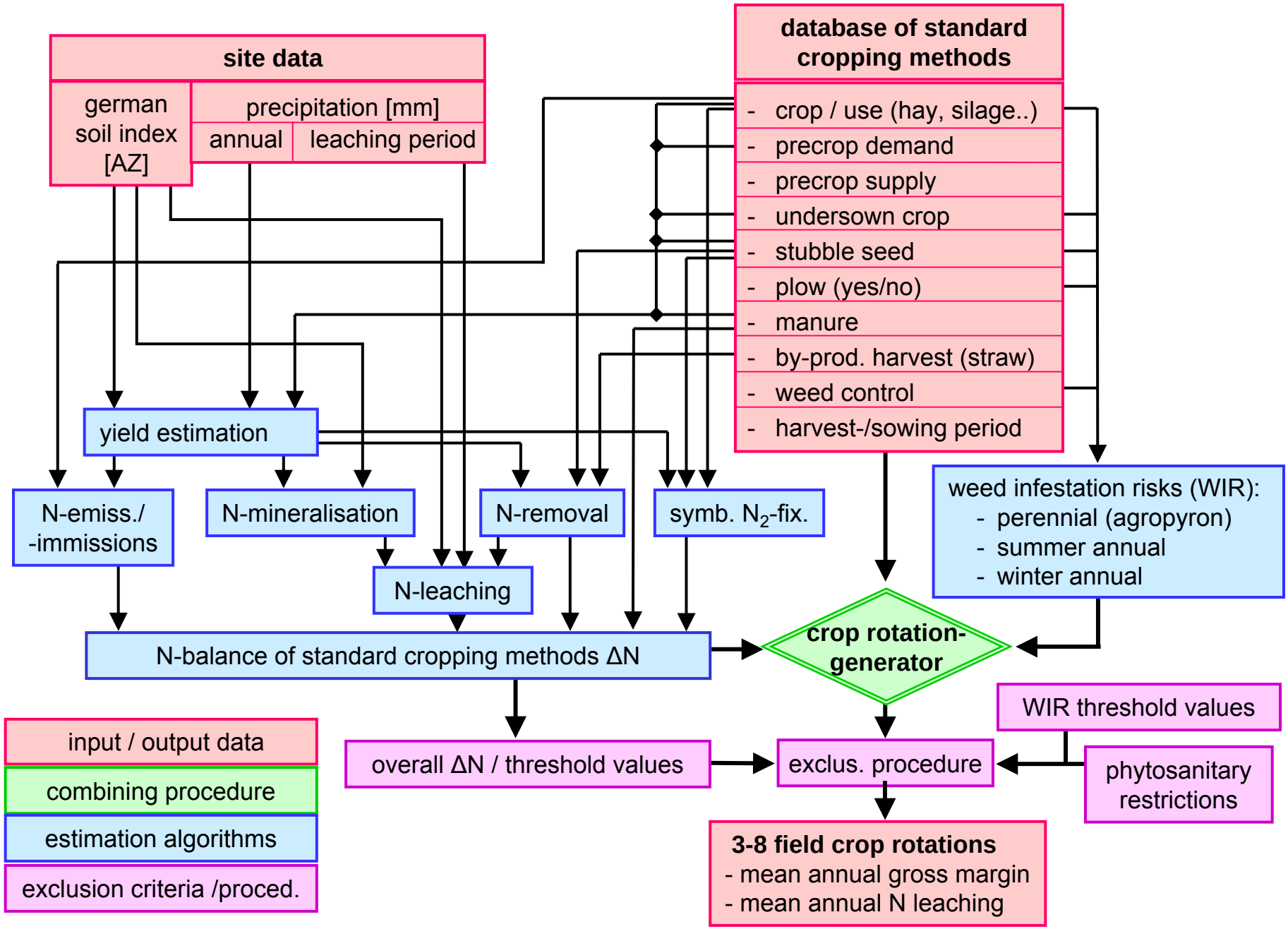


Comparison between yield calculated with the yield functions of ROTOR (a) without and (b) with the use of preceding crop dependent yield levels and observations based on a survey of 8 organic farms (1999 and 2000)

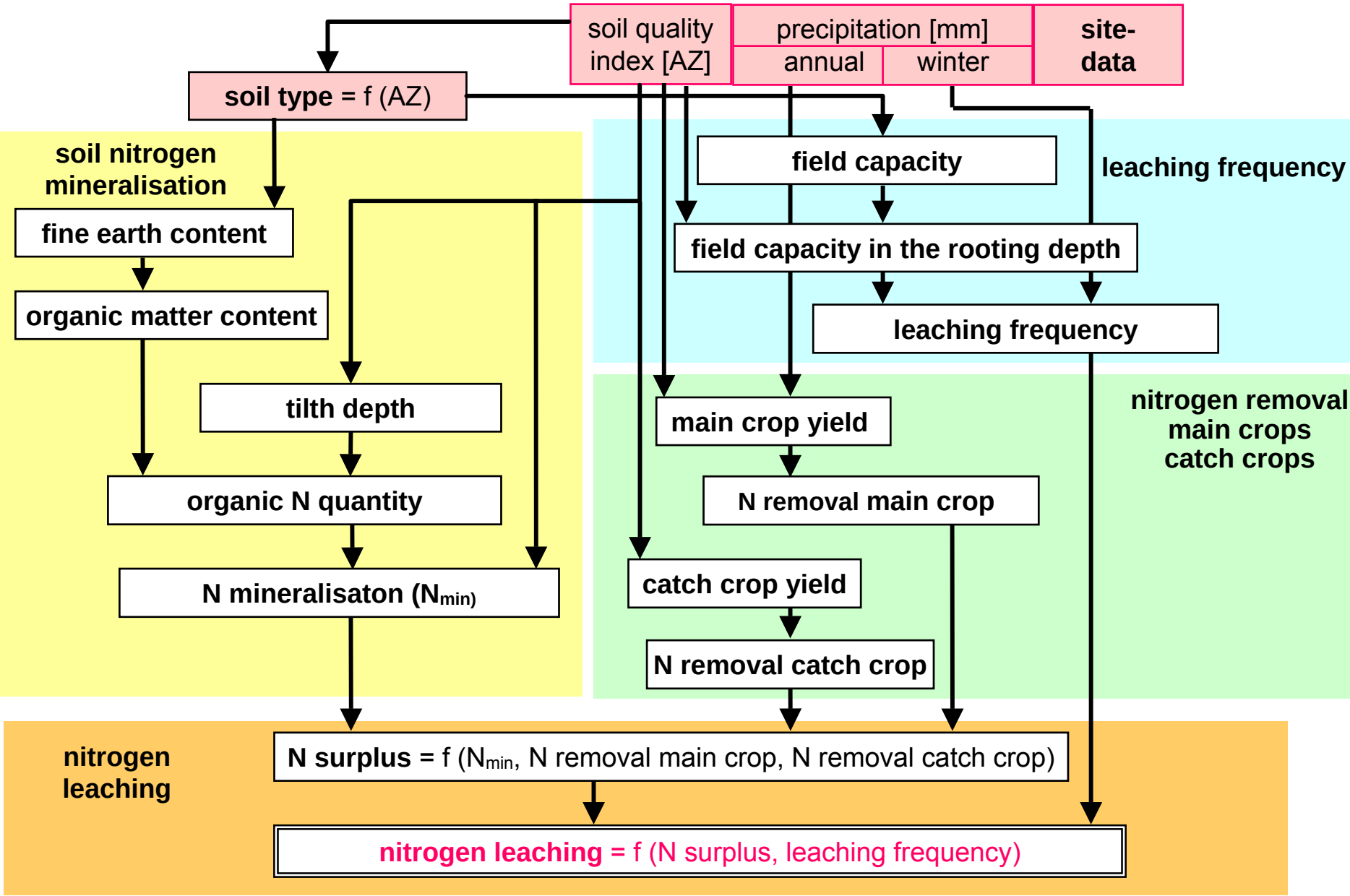


Oat (OAT); Spring barley (SBA); Winter rye (WRY); Winter wheat (WWH).

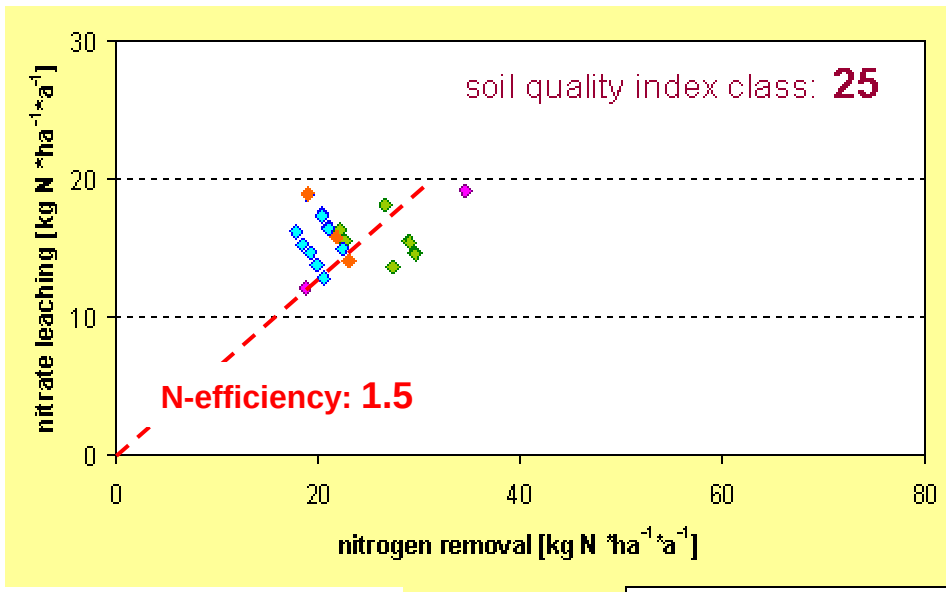
Model structure of the crop rotation planning tool

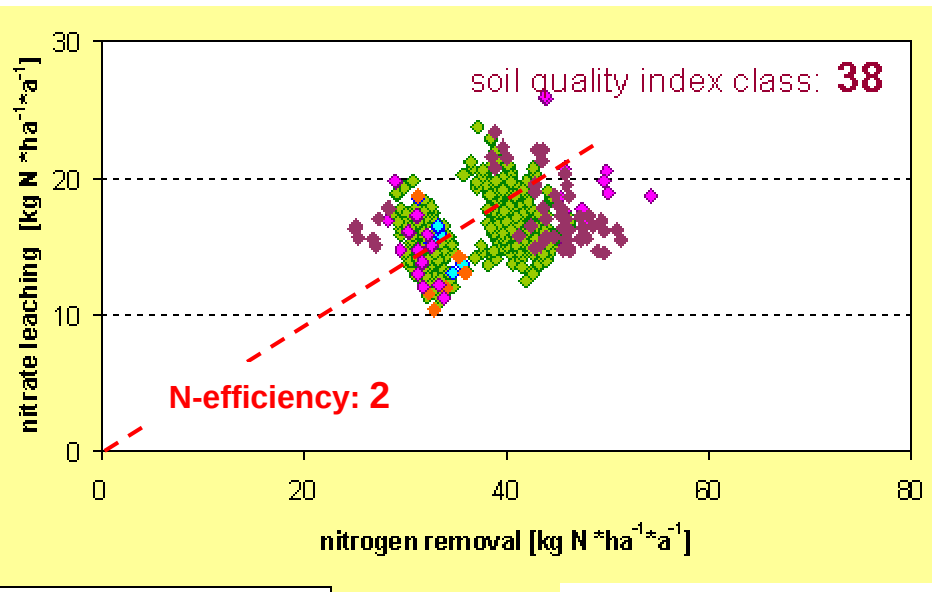


Calculation of the annual N-leaching of standardized cropping methods

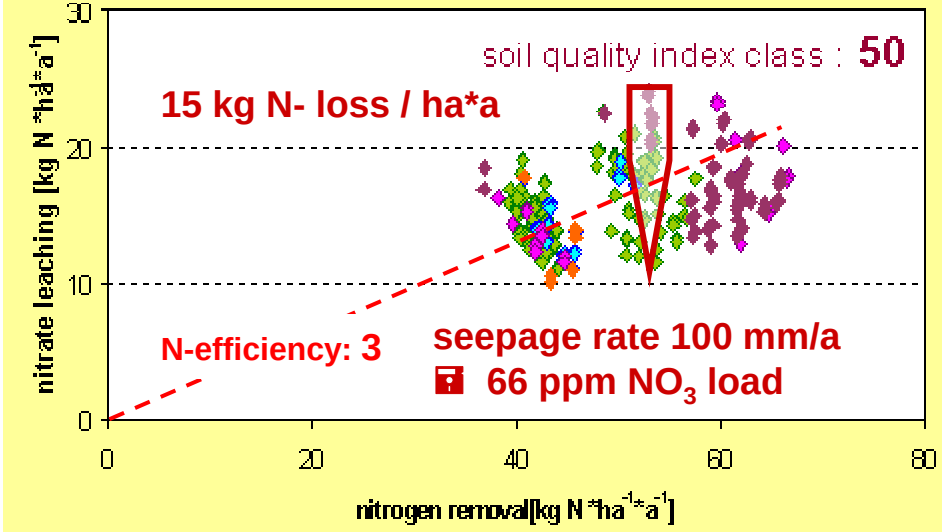


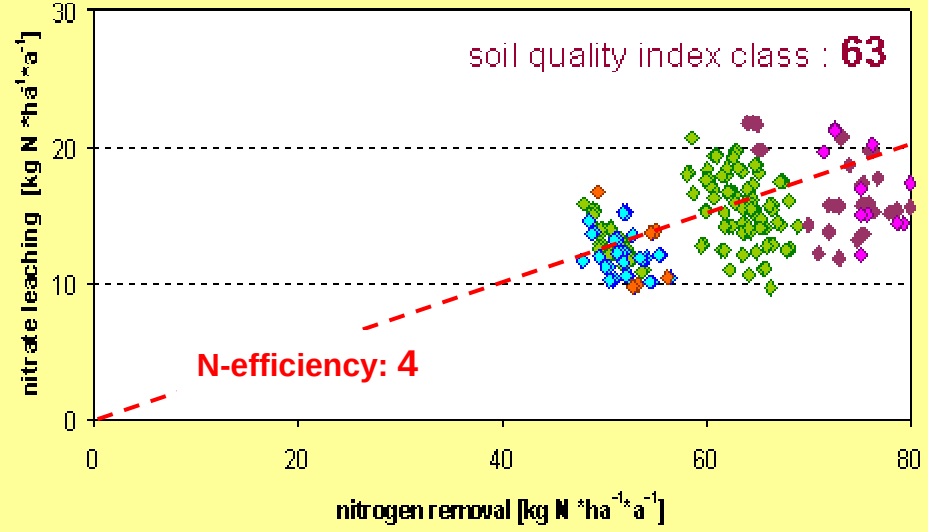
Calculated Annual Nitrate Leaching Versus Nitrogen Removal by Harvest Products for Different 3 to 7-field Crop Rotations of Organic Cash Crop Farms at Four Soil Quality Levels in Northern Brandenburg (500 mm annual Prec.)





7f-CR 6f-CR 5f-CR 4f-CR 3f-CR





Categories for preceding crops and the coding rules for combining standardised cultural methods within the crop rotation generator

Coding crop categories for describing the yield effects (three yield levels) of a preceding crop on a following main crop:

11 / 12	=	cereals with low / high positive yield effect	→	low / medium
21 / 22	=	leaf (row) crop with low / high positive yield effect	→	medium / high
31 / 32	=	grain legumes with low / high positive yield effect	→	medium / high
41 / 42	=	legume grass with low / high positive yield effect	→	medium / high

Additional coding categories for the integration of undersown catch and forage crops:

a	=	no special demand
g	=	grass undersown in grain legumes
l	=	legume grass as a catch crop undersown in cereals
f	=	establishment of legume grass as main crop with / without companion crop